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ABSTRACT

This report summarizes the results of an evaluation of the thinking skills model/program developed at the Mid-continent Regional Educational Laboratory (McREL). Participating were 19 primary, 32 upper elementary, 10 junior high, and 16 senior high school teachers at four sites varying in size and locale. Providing a framework for teaching a wide range of thinking skills within content area classrooms, the thinking skills model includes three general categories of cognitive skills considered relevant to academic success: (1) learning-to-learn skills, (2) content thinking skills, and (3) basic reasoning skills. Altogether, 18 skills areas are included in the model. Each is hypothesized to affect different student behaviors and to be associated with a particular rationale for the hypothesized effect; each was assessed with different measures within either one-shot case study or pretest-posttest designs. Trained in four spaced sessions, the 77 participating teachers pilot-tested the thinking skills techniques on over 1,900 students. Data were obtained through teacher-made tests, interviews with students, and observations of students by teachers. Results are reported for each skill area of the model: attention control, goal setting, attitude change, self-evaluation, concept attainment, pattern recognition, synthesizing, proceduralizing, deep processing, use of memory frameworks, categorizing, extrapolation, analogical reasoning, evaluation of evidence, evaluation of value, elaboration, problem solving, and invention. References are included. (RH)

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AN EVALUATION OF THE McREL THINKING SKILLS PROGRAM

by
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January, 1986

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INTRODUCTION

The purpose of this report is to summarize the results of the efforts to evaluate the thinking skills program developed at the Mid-continent Regional Educational Laboratory. The program as initially conceived is meant to be a framework for teaching a wide range of thinking skills within content area classrooms. That is, the model was developed to be as broad as possible (encompass as many skills as possible) and to be implemented in a regular classroom setting as opposed to a special course or courses in "thinking skills."

Given this overall intention the first step in the process of developing the McREL program was to survey the literature on cognition, artificial intelligence, developmental psychology, information processing and many other cognate fields. The research and theory from these fields were then translated into instructional strategies. That is, for the major theories and research findings within each of the cognate areas an attempt was made to develop a set of instructional practices. For some of the theories and research findings from these diverse fields, classroom application was difficult. In such cases, the theory or research finding was dropped from the model. The remaining components were then field tested for teacher acceptance. Teachers from various grade levels reviewed the strategies and offered suggestions as to how strategies might be changed to improve their classroom effectiveness. During this second level screening some instructional techniques were also dropped from the model as a result of the feedback from teachers. The remaining strategies were then fit into a conceptual framework -- a unifying theory of cognition which housed all strategies. Again, this was considered a level of screening. Strategies which survived the first two levels of screening were dropped from the model if they did not fit into the conceptual framework.

This report describes the field testing results for those strategies included in the conceptual framework. Below a brief description of that framework is provided. For a detailed description see Marzano (1985a, 1985b) or Marzano and Hutchins (1985).

THE THINKING SKILLS MODEL

A primary thesis of the McREL thinking skills model is that a majority of the cognitive skills considered relevant to academic success can be categorized into three distinct groups: 1) learning-to-learn skills, 2) content thinking skills and 3) basic reasoning skills. We consider each below:

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Learning-to-Learn Skills:

The learning-to-learn skills are those which facilitate learning of all types. The basic assumption underlying the learning-to-learn skills is that learning within a classroom setting is a function of generalized competencies that are used in all learning situations -- not just those related to school. If students are taught or made aware of these generalized competencies, they can use them in any situation -- school related and non-school related. There are four general competencies in the learning-to-learn area: 1) attention control, 2) goal setting, 3) monitoring attitudes and 4) self-evaluation.

Attention control involves an awareness on the part of students of when they are and are not attending to a task. Within cognitive psychology, two types of attention are commonly identified: automatic and voluntary (Luria, 1983). Automatic attention is basically reflexive in nature; voluntary attention occurs when an individual willfully shifts attention to or maintains attention on a specific stimulus. The intent of the thinking skill entitled attention control is to provide students with an awareness of when they are and are not attending and a set of strategies for shifting attention when they so desire.

Goal setting is the skill of identifying an explicit outcome and planning activities to accomplish that outcome. Over forty years ago, Sears (1940) found that successful students tended to set explicit goals. More recently Brophy (1982) found that successful students tended to set goals that were challenging but reasonable. Bandura and Schunk (1981) found that classroom goals should be short term (proximal) rather than long term (distal) to be most effective.

Once a goal is set an individual will generally consider some high level controlling attitudes relative to the goal. A high level controlling attitude can be described as a basic operating principle which governs behavior. These principles are so important to human behavior that some theorist have hypothesized the existence of a specific type of memory housing then called "executive memory." (e.g. Sternberg, 1984). Within the thinking skills program students are taught to identify and foster specific attitudes which facilitate the accomplishment of academic goals (e.g. commitment to precision and involvement).

During the attainment of a goal, effective learners commonly engage in self-evaluation techniques in which they identify what is working and what is not working relative to the goal. This can be done both formatively and summatively. That is, students can monitor the effectiveness of their activities while they engage in a task and after they have completed the task.

Content Thinking Skills

The purpose of the content thinking skills is to provide students with a set of information processing strategies which facilitate the learning of academic content sometimes referred to as domain specific knowledge (Doyle, 1983). There are four content thinking skills within the thinking skills program: 1) concept attainment, 2) pattern recognition, 3) synthesizing and 4) proceduralization.

Concept attainment is the process of attaining the culturally accepted labels for a set of experiences. According to Klausmeier and Sipple (1980) a concept is the "socially accepted meaning of one or more words which express the concept." For example, the word dog is the label society uses to represent the conceptualization of a set of four-legged animals with certain characteristics. Within the thinking skills program concept attainment refers to: 1) the development of an experiential base for the concept, 2) the recognition of the auditory label for the concept, 3) the recognition of the orthographic label for the concept and 4) the development of an accurate description of the concept.

Patterns are organizational structures which hold together large blocks of information. There are two levels of patterns taught within the thinking skills program - basic patterns and macro-patterns. Basic patterns are used to organize linguistic information from the size of a paragraph to a few pages, or even a chapter of a textbook. Macro-patterns are used to organize even larger blocks of linguistic information (e.g. an entire book).

Synthesizing is the process of expressing information read or heard in a streamlined version referred to as a macro-structure (Kintsch and van Dijk, 1978). This generally involves such techniques as identifying summary statements, generating summary statements when none exist and subsuming specific concepts under more general concepts.

Proceduralization is the process of: 1) identifying the relevant steps in a specific process, 2) rehearsing these steps with the intent of "smoothing them out" (dropping steps that are inefficient and adding steps that are more efficient), 3) practicing the process until it reaches a level of automaticity. This sequence for procedure learning was first described by Fitts (1964) and later expanded by Anderson (1983).

Basic Reasoning Skills

Reasoning skills are those considered basic to many cognitive tasks. According to Anderson (1983) reasoning skills can be subdivided into three general classes: 1) those that foster storage and retrieval of information, 2) those that match one set of information with the other and 3) those that drastically restructure old information or build new information.

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1. Storage and Retrieval

There are two basic storage and retrieval skills: 1) deep processing and 2) memory frameworks. Deep processing is the use of imagery to enhance incoming information. According to Sheikh (1983), imagery involves the creation of mental pictures, sounds, tastes, smells, noises and emotions about information. Apparently, with practice, people can enhance their imagery skills (Bellezza, 1983).

Memory frameworks create "slots" in which sequential information can be deposited using deep processing. Within this category are loci methods (Ross & Lawrence, 1968) and pegword methods (Lindsay & Norman, 1977).

2. Matching Skills

Matching skills are those which enable an individual to identify how incoming information is similar to and different from information stored in long term memory. There are five types of matching skills: 1) categorization, 2) extrapolation, 3) analogical reasoning, 4) evaluation of logic and 5) evaluation of value.

According to Mervis (1980), categorization is an essential skill because "by categorizing a person is able to render the unfamiliar familiar and because one is able to generalize about an object based on knowledge about its category, one is able to know more about the object than just what can be ascertained by looking at it" (p 279).

Within the thinking skills program, categorization is practiced as an adjunct skill to concept development. That is, students are asked to categorize new vocabulary words by their relevant attributes.

Extrapolation is the process of matching the pattern of information read or heard with that of information from a different subject area or a different context. According to Alston (1964) this type of thinking is similar to the basics of metaphor.

Analogical reasoning is one of the most commonly included elements within thinking skills instructional models. According to Alexander (1984) few intellectual skills are as pervasive or essential as the ability to reason analogically. Within the McREL program, analogical thinking is taught using an adaptation of the four step process described by Sternberg (1977).

Evaluation of evidence is the process of matching the structure of information with some formalized system of logic. Within this model, the logic system developed by Toulmin (1958); (Toulmin, Rieke & Janik, 1977) is used as the logic criterion.

Evaluation of value is the process of matching information to some internalized system and then analyzing the logic of that value system. Spiro (1980) has stated that this "attitudinal" characteristic of thinking is the central aspect of cognition because it allows one to see the information base from which judgments are made.

3. Knowledge Building & Reorganization

There are three knowledge building and restructuring skills within the program: 1) elaboration, 2) problem solving and 3) invention.

Elaboration refers to inferring information not explicitly stated. Various categories of inference have been proposed by teachers and theorists (e.g. Bruce & Schmidt, 1974; Warren, 1979). Within this model three types of inferences are used: 1) elaboration of characteristics, 2) elaboration of casuality, 3) elaboration of general background and 4) elaboration of author purpose.

Problem-solving occurs when an individual must "fill-in" missing information. This is at the core of all problems; a goal is desired and information necessary to accomplish the goal is missing. Within the McREL model problem solving heuristics have been developed for general, everyday problems, mathematical problems, science problems, problems of constraining conditions and problems of unusual contexts.

Invention is the process of creating new information or new products. This involves conceiving an idea, planning for its development, creating a working model and then revising or fine tuning the model until it reaches a polished state. Within mainstream education this process is generally taught as composing in written form. Within the thinking skills program it is taught as a general heuristic for the creation of any product.

THE TRAINING PROGRAM

The eighteen skill areas described above are generally presented to teachers as a single intervention - a comprehensive program. The order of presentation to teachers generally follow that described above. That is, teachers are first presented techniques for the learning-to-learn skills, then techniques for the content thinking skills and finally techniques for the basic reasoning skills. The training usually takes four days (1 day for the learning-to-learn skills, 1 day for the content thinking skills, and 2 days for the reasoning skills). Each day of the training is spaced 2 to 5 weeks from preceding and subsequent training days. During the time between trainings participating teachers collect data on the effectiveness of the various techniques. At the end of the four days of training participating teachers use the data to make informed decisions as to which techniques work well for them and which techniques do not work well. For the most part it was teacher collected data that was used for the evaluation.

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DEPENDENT VARIABLES

Although the eighteen thinking skills are presented as a single intervention, they are hypothesized to affect different student behaviors. That is, the eighteen components of the independent variable (the thinking skills program) were hypothesized to affect different dependent variables.

Below the dependent measures for each of the eighteen areas are briefly described.

Skill Area	Hypothesized Effect	Dependent Measure
1. Attention control	-increased task engagement	-engaged time -engagement rate -teacher observation
2. Goal setting	-increased success in academic goals	-success rate -teacher observation
3. Monitoring attitudes	-increased effort attribution relative to goals	-student interviews -teacher observation
4. Self-evaluation	-increased metacognitive awareness of effective and ineffective actions	-student interviews -teacher observation
5. Concept attainment	-understanding of basic meaning of target concepts; recognition of phonemic and orthograph representation of the concept	-teacher made vocabulary and spelling tests -teacher observation
6. Pattern recognition	-increased ability to organize large blocks of information	-teacher made tests -teacher observation
7. Synthesizing	-increased ability to express the macrostructure of information	-teacher observation
8. Proceduralizing	-increased ability to internalize complex procedures	-teacher observation
9. Deep processing	-increased ability to elaborate on the imagery characteristics of information -increased ability to recall information	-teacher observation
10. Memory framework	-increased ability to recall information sequentially	-teacher made tests

11. Categorizing	-increased ability to organize concepts into semantic categories -increased ability to identify shared attributes among sets of concepts	-teacher made tests -teacher observation
12. Extrapolation	-increased ability to recognize similarities and differences between sets of information from different sources	-teacher made tests -teacher observation
13. Analogical reasoning	-increased ability to solve analogy problems	-teacher made tests -teacher observation
14. Evaluation of evidence	-increased ability to determine whether a claim is supported or unsupported	-teacher made tests -teacher observation
15. Evaluation of value	-increased ability to identify the assumptions underlying personal values and the basis for those assumptions	-student interviews -teacher observation
16. Elaboration	-increased ability to identify unstated characteristics, causes and intentions	-teacher observation
17. Problem solving	-increased metacognitive awareness of processes for solving specific problems -increased ability to solve specific problem types	-teacher observation -student interviews
18. Invention	-increased ability to conceive of a product and develop it to a final format	-teacher observation

A brief description of the rationale for the hypothesized effects for each component of the program is presented below:

Skill Area	Rationale for Hypothesized Effect
1. Attention control	-increased awareness of level of attention and incidence of attention will provide more student control over task engagement

2. Goal setting	-increased specificity of academic goals will provide heightened awareness of goal related activity and non-goal related activity. This will increase goal related activity which will increase goal accomplishment.
3. Monitoring	-increased awareness of negative attitudes about academic tasks along with cognitive restructuring activities will increase an effort attribution about success at school work.
4. Self-evaluation	-increased attention to feedback as to the formative success of a task will increase student ability to judge the effectiveness of actions.
5. Concept	-identification of imagery characteristics of a concept along with semantic attributes will strengthen understanding, recall and recognition of concepts.
6. Pattern recognition	-increased awareness of linguistic patterns will increase ability to organize and retrieve text based information.
7. Synthesizing	-increased awareness of linguistic patterns will strengthen ability to identify important elements of linguistic information.
8. Proceduralizing	-increased awareness of the stages of procedural learning will increase attention to the stages which will improve acquisition of complex processes.
9. Deep processing	-increased awareness of imagery characteristics of information will increase access to implied information. -increased attention to imagery characteristics of information will increase the number of cues associated with the information.
10. Memory	-use of pegwood and loci mnemonic methods will improve serial retrieval of information.
11. Categorizing	-increased awareness of types of semantic features will increase awareness of the different ways concepts are similar and dissemination.
12. Extrapolation	-increased awareness of shared organizational patterns of information will increase awareness of the ways large blocks of information can be similar and dissimilar.
13. Analogical reasoning	-increased awareness of relationships commonly involved in analogy problems will increase ability to solve analogies.
14. Evaluation of evidence	-increased awareness of informal falacies and unsupportable claims will increase ability to identify unsubstantiated claims.

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15. Evaluation of value	-increased awareness of the characteristics of value judgments will increase ability to identify the underlying beliefs and assumptions which are the basis for personal value judgment.
16. Elaboration	-increased awareness of the structure of various types of information will increase access to stored information.
17. Problem solving	-increased awareness of essential elements of various problem types (e.g., givens, operations, goals) will increase the efficiency of problem solving.
18. Invention	-increased awareness of phases of invention will increase the effectiveness of the invention process.

In addition to the elements described above which were assumed to generate the hypothesized effects, each skill included a specific procedure to be taught to students. For example, for the skill of attention control students were presented with a specific set of steps which were considered heuristic rather than algorithmic (general "rules of thumb to follow" rather than a rigid set of steps). Beyer (1984) has suggested that lack of explicit instruction in procedures is one of the major causes of student failure to understand and utilize thinking skills.

SUBJECTS

The subjects for the evaluation were drawn from four sites where the thinking skills program was pilot tested. Those sites are described below:

Site #1 was a large suburban school district serving over 6000 students of mixed socio-economic strata. Twelve teachers from this district participated in the study. They represented the following grade levels:

Grade Level	No of Teachers
Primary	4
Upper Elementary	3
Junior High	2
Senior High	3

Site #2 was a small rural school district serving about 700 students. Twenty-four teachers from the district participated in the study. The grade levels represented are listed below:

Grade Level	No.of Teachers
Primary	8
Upper Elementary	9
Junior High	4
Senior High	3

Site #3 was a large rural district serving about 800 students. Thirty-five teachers participated in the study:

Grade Level	No. of Teachers
Primary	5
Upper Elementary	16
Junior High	4
Senior High	10

Site #4 was a single elementary school. Here six teachers participated in the study:

Grade Level	No. of Teachers
Primary	2
Upper Elementary	4

Including all four sites, the evaluation study included the following distribution of teachers:

Grade Level	No. of Teachers
Primary	4 + 8 + 5 + 2 =19
Upper Elementary	3 + 9 + 16 + 4=32
Junior High	2 + 4 + 4 =10
Senior High	3 + 3 + 10 =16
	Total =77

The 77 teachers involved in the study pilot tested the thinking skills techniques on over 1900 students.

DATA COLLECTION

For sites 1-3 data were collected by participating teachers between training sessions. That is, after training session #1 participating teachers collected data on the techniques presented during session #1; after session #2 teachers collected data on the techniques presented in session #2; etc. At site #4 the data were collected by the trainer. Site #4 utilized a different training format. Participating teachers first went through all four days of the training. The techniques were then pilot tested in an after school program in which students voluntarily participated. The trainer was present at all sessions and utilized those sessions to collect types of data that could not be collected from participating teachers.

INSTRUMENTATION

All tests used to assess academic performance were teacher made. No reliability or validity data were collected on those instruments. Similarly, the teacher observation data were collected in anecdotal fashion. That is, for the observational data, teachers simply recorded their perceptions of student changes in behavior. For the success rate and engagement rate data collected by the trainer a formal observation systems were utilized. The trainer also used a formal system of protocol analysis to analyze the information obtained from student interviews.

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LIMITATIONS

The limitations of the present evaluation effort were many. One obvious limitation is that the effects of the various thinking skill techniques can not be considered independent since the training was presented in a sequential fashion. Even though the theory base underlying the various skill areas would indicate that their effects might be relatively independent, the evaluation design was such that the skills taught earlier in the sequence could mask the effects of skills taught later in the sequence or create an effect not related to the technique under investigation.

For most of the skill areas the evaluation design was what Campbell and Stanley (1963) refer to as a one-shot case study. In such designs the dependent variable is measured after the intervention. According to Campbell & Stanley (1963) such a design has the following threats to internal and external validity:

-history
-maturation
-interaction of selection and treatment

For those skill areas for which pretest data could be collected, a pretest-posttest design was used. According to Campbell and Stanley, such a design has the following threats to internal and external validity:

-history
-maturation
-testing
-instrumentation
-interaction of selection,maturation, etc.
-interaction of testing and treatment
-interaction of selection and treatment

RESULTS

Below the results for each of the 18 skill areas are discussed. Since all teachers in the study did not collect data on all skill areas, the number of teachers reporting varies from skill area to skill area.

1. Attention Control

The effect for attention control was measured using teacher anecdotal comments, engaged time and engagement rate. Teacher anecdotal comments were reported by 65 teachers. Of those 51 reported that students were more aware of when they were and were not engaged and exhibited more control over their attending behavior as a result of the attention control process. Fourteen teachers reported no noticeable change in student attending behaviors.

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Engaged time and engagement rate were collected by the investigator in a pre-post fashion in 6 classrooms. Engaged time is expressed as a proportion of total class time. Engagement rate is expressed as the ratio of time engaged over the time devoted to academic tasks. The results for engaged time and engagement rate are reported below:

Engaged Time

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.75	.73	.02	5	.13	NS

ENGAGEMENT RATE

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.81	.91	.10	5	3.01	.05

T-test results showed no significant difference in engaged time but did show a significant difference in engagement rate. This indicates that students did not experience more engaged time probably due to the increased amount of non-instructional time necessary to administer the technique. However, students did exhibit a significant increase in engagement rate while instruction was occurring. This indicates that as a result of the attention control process students do exhibit more control over their attending behavior and more frequently choose to attend to the academic tasks presented to them.

2. Goal Setting

Goal setting was evaluated using teacher anecdotal data and success rate data. Anecdotal data were collected by 61 teachers. Of those, 53 reported that having students set explicit short term goals increased student success as measured by responses to teacher questions and in-class assignments. Fifteen participating teachers reported pre- and post-test classroom exercise data. Scores were transformed to proportions and two-tailed t-tests for dependent groups run:

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.81	.88	.07	175	4.05	.001

Pre-post engagement rate data were collected on 6 teachers.

The results for a two-tailed, t-test for dependent groups are:

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.79	.91	.12	5	8.17	.001

Pre-test and post-test analyses for both classroom exercise and success rate data showed significant gains at the .001 level. This was interpreted as an indication that increased attention to and specificity of academic goals increases metacognitive control of the goal attainment process.

3. Monitoring Attitudes

Student attitude change was assessed using teaching observation and student interview data. Teacher observation data were reported by 36 teachers. Of those, only 7 reported an observable change in student behavior as a result of the attitude monitoring techniques. However, 29 teachers also reported that they experienced an increased ability to communicate with the more troublesome students about specific problems within the class.

Self report data were collected from 7 students. Of those, 5 reported that they could see why certain attitudes about certain classes were "getting in their way." These findings appear consistent with much of the research on attitude change -- namely that attitudes can change without any observable behavior change. This might explain why only seven teachers reported changes in student behavior but 29 reported more open communication with troublesome students. It might be that students attitudes actually had begun to change resulting in more open communication. However, this attitude change had not as yet been translated into behavior change.

4. Self-evaluation

The effect of the self-evaluation technique were assessed using teacher observation and student interview data. Anecdotal data were reported by 34 of the 77 participating teachers. Of those, 29 stated that the self-evaluation techniques began to foster a self-awareness on the part of students of efficient and inefficient activities relative to completing a task. The remaining five reported no noticeable effect on students.

Interview data were collected from 7 students - all 7 of which reported that the self-evaluation techniques made them more aware of when they were and were not being efficient.

These findings were interpreted as an indication that self-evaluation techniques increase metacognitive control of task performance and consequent efficiency of task behavior.

5. Concept Attainment

Teacher observation and teacher made test data were collected to measure the effects of the concept attainment strategies. Sixty-five

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participating teachers reported on the concept attainment process. Of those, 54 stated that they saw a definite improvement in students' knowledge of concepts as a result of the strategies.

Seventeen teachers reported pre-post scores on teacher made vocabulary tests. Results from a two-tailed, t-test for dependent groups are reported below:

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.83	.94	.11	145	10.17	.001

Eleven teachers reported pre-post scores on teacher made spelling tests. Results from a two-tailed t-test for dependent groups were:

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.74	.81	.08	97	11.12	.001

Both the vocabulary and spelling tests showed significant increases in scores as a result of the concept development techniques.

These results were primarily attributed to the imagery aspects of the concept attainment process. This was evident in the ancedotal comments of the teachers. That is, many of those teachers who reported an effect for the concept attainment process emphasized the importance and power of the imagery component.

6. Pattern Recognition

Data on pattern recognition were collected via teacher observation and teacher made tests. Sixty-one teachers provided anecdotal data. Fifty-four of those, indicated that the pattern recognition techniques significantly improved students' abilities to understand material they read.

Twelve teachers reported pre-post test data on student comprehension. Results from a two-tailed t-test for dependent groups are reported below:

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.74	.83	.09	168	15.51	.001

Results indicated a significant increase in students' comprehension ability as a result of the pattern recognition training.

Further analysis of teacher anecdotal data strongly suggested that this is due to the use of patterns as an organizational tool. That is, students used the patterns as organizational frameworks which they superimposed on the information they read.

7. Synthesizing

Teacher observation was the only type of data collected on the skill of synthesizing. Twenty-three teachers reported on this technique. Of those, 17 indicated significant increase in study ability to synthesize information as a result of the technique. Again the anecdotal comments indicated that a key component of the synthesizing process was the use of patterns as a tool for organization.

8. Proceduralizing

Due to its relatively late inclusion in the thinking skills model, only four teachers reported on the effects of the proceduralizing techniques. All four indicated that this was a very difficult skill to teach students. None saw any immediate change in student behavior but all felt that over time this skill would effect useful changes in student behavior. More specifically the participating teachers reported that the level of specificity reached exceeded that usually reached for classroom procedures. They stated that an increased attendion to detail would increase the level of learning for classroom procedures.

9. Deep Processing

Evaluation data for the technique, deep processing, were collected via teacher observation. Fifty-nine teachers reported. Forty-seven of those indicated that the deep processing technique increased students' abilities to elaborate on the imagery characteristics of information and to recall information once it had been deep processed. More specifically, they reported that the imagery aspects of deep processing made students aware of aspects of information for which they were previously unaware.

10. Memory Frameworks

Teacher made tests were used to evaluate the use of memory frameworks. Twenty-five teachers reported pre-post results:

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.46	.78	.32	161	25.71	.001

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A significant increase in students' abilities to recall information sequentially is indicated from these findings.

These findings are consistent with much of the research on memory frameworks -- namely that memory frameworks, increase retrieval of information. However, the difference between these findings and previous ones is the use of pattern recognition as a vehicle for organizing information prior to the use of memory frameworks. More specifically most previous research was conducted using fairly simple, concrete concepts. Here large blocks of information were stored in each slot of the memory frameworks. The blocks were organized using patterns.

11. Categorizing

Teacher observation and teacher made test data were used to assess the categorizing technique. Seventeen teachers provided anecdotal comments. Fourteen indicated that categorizing helped students understand the meaning of concepts and their defining attributes

Six teachers turned in pre-post test data. The results of a two-tailed,t-test for dependent groups were:

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.85	.88	.03	45	1.04	N.S.

Although there was a slight gain in student performance on tests of concept knowledge, this gain was not significant statistically. Anecdotal comments indicated that the attribute frames used for categorization helped students develop rules for categorization. However, the categorizing process still presented students with difficulty.

12. Extrapolation

Extrapolation was assessed using teacher observation data and teacher made tests. Observation data were supplied by 21 teachers. Seventeen reported that the technique increased students' abilities to see relationships between seemingly unrelated sets of information.

Ten teachers reported test data. The results of two-tailed, t-test for dependent groups are reported below:

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.81	.95	.14	65	5.01	.001

The analyses indicated a significant increase in students' abilities to extrapolate information.

Again teachers reported that pattern recognition was key to the extrapolation process. Once students recognized the pattern of information, they then had a framework which they could use to identify similar information from a different context.

13. Analogical Reasoning

Analogical reasoning was assessed using teacher observation and teacher made tests. Thirty-seven teachers reported anecdotal data. Of those, 26 stated that direct teaching of the technique for analogical reasoning improved students' abilities to solve analogy problems

Ten teachers reported pre-post test data. A two-tailed t-test for dependent groups showed significant results at the .001 level

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.86	.94	.08	91	7.35	.001

As reported by teachers the most powerful component of the analogical reasoning process was direct instruction in the semantic relationships found in analogy problems. Once students were aware of these relationships their ability to solve analogy problems increased.

14. Evaluation of Evidence

Both teacher observation and teacher made test data were used to assess the skill, evaluation of evidence. Twenty-two teachers reported anecdotal data. Seventeen stated that they observed an increase in students' abilities to evaluate the logic of a claim. However, a two-tailed t-test for dependent groups on the test data reported by three teachers did not show significant results.

Pre-test Mean	Post-test Mean	Difference	df	T-value	Sig
.79	.81	.03	19	.79	N.S

As an explanation of the discrepant results between anecdotal and classroom test data, teachers reported a low level of confidence in the validity of their tests. That is, they expressed doubt that their teacher made tests actually measured student ability to evaluate evidence while at the same time expressing more confidence in their informal observations.

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15. Evaluation of Value

Evaluation of value was assessed using teacher observation and student self-report data. Twenty five teachers reported anecdotal data. Of those, 21 stated that the evaluation of value process increased students' abilities to identify the assumptions underlying their assignment of value and to identify different points of view which might generate different value judgments.

Seven students were interviewed about the effects of the evaluation of value process. All seven students indicated that the process provided them with a new level of insight into what attitudes and values are and how they are formed.

16. Elaboration

Data on elaboration were collected via teacher observation only. Forty-one teachers reported. Of these, 37 stated that the elaboration process increased students' abilities to identify unstated characteristics, causes and intentions. That is, the elaboration process provided a framework which allowed students to identify implied information. Apparently this information was available to students but not easily accessed. The frameworks provided by the elaboration process apparently increased access.

17. Problem Solving

Problem solving was assessed using teacher observation and student interviews. Eighteen teachers provided observational data. Twelve indicated that the problem solving techniques improved students' abilities to solve specific content related problems. Self-report data were collected from five students, all of whom indicated that the problem solving techniques presented them with a systematic way to approach and solve problems.

Despite the generally positive results for the problem solving process many teachers reported that the problem solving heuristics presented to students were too general in nature. This implies a need for more specific problem solving heuristics for different problem types.

18. Invention

Invention was assessed via teacher observation only. Twelve teachers reported. Of those, nine stated that the invention process significantly improved students' abilities to conceive of, develop and carry through to completion projects involving the creation of new products. These teachers reported that the incubation and discovery phase of the invention process was the most useful component. It provided students with a method for translating imagery information into a linguistic form.

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DISCUSSION

All eighteen of the skills involved in the thinking skills program produced measurable effects in student behavior to one degree or another. This is not surprising in light of the fact that the thinking skills model went through a set of screening phases described previously. One might say that the model which was formally tested was a fourth generation model. It would be expected, then, that those skills remaining after such a filtering process would produce positive effects.

Given the limitations to the evaluation design discussed previously these findings can not be considered stable. That is, given the threats to internal and external validity inherent in the evaluation design we cannot conclude that the measured effects for each skill area are a function of the training program. However, given the state of the art of thinking skills instruction, the findings for the McREL program indicate that it compares well with other programs. More specifically in the major review of current thinking skill programs compiled by Segal, Chipman and Glaser (1983), it was reported that many of the current programs which are in wide use (some for over ten years) do not have a strong research base or a strong evaluation data base. In many cases, the McREL program actually has evaluation data that is more comprehensive and which is derived from a sounder evaluation design even though it has been in use a relatively short period of time. Currently, controlled experiments are being conducted on each component of the McREL program to further refine the model and more specifically identify the effects produced by each component of the model.

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